MECHANICAL ENGINEERING

PAPER-II

Time Allowed: **Three Hours** Maximum Marks: **300**

Question Paper Specific Instructions

Please reach each of the following instruction carefully before attempting questions:

*There are **EIGHT** questions divided in **TWO** sections.*

*Candidate has to attempt **FIVE** questions in all*

*Questions **No.1** and **5** are **compulsory** and out of the remaining, any **THREE** are to be attempted choosing at least **ONE** question from each section.*

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams/figures, wherever required, shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and rotations carry their usual standard meanings.

Psychometric Chart is given in Page No.8.

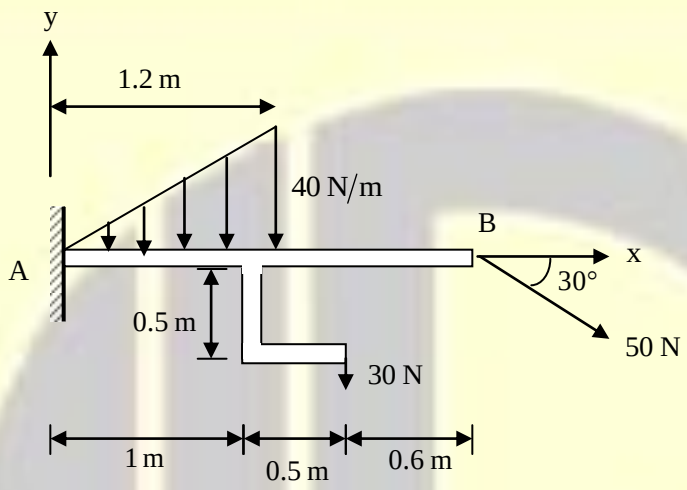
Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the QCA Booklet must be clearly struck off.

*Answers must be written in **ENLISH** only.*

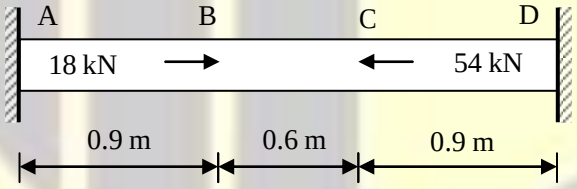
SECTION-A

1. **(a)** Find the support reaction at the fixed end A of the loaded beam:



[12 Marks]

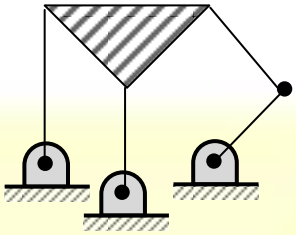
(b) The straight bar AD of uniform cross-section is attached to the rigid end supports. Find the force acting on any cross-section in the regions AB, BC and CD:



[12 Marks]

(c) (i) Determine the degrees of freedom of the following planar linkages/kinematic chains:

1.



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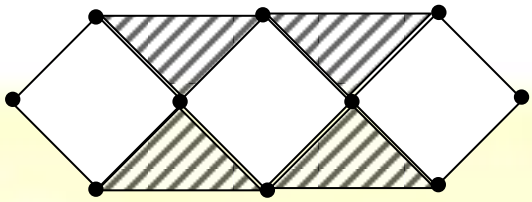

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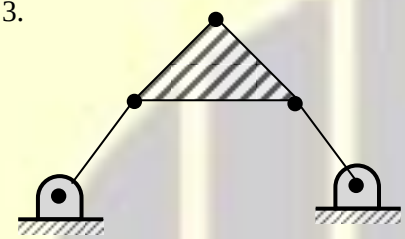

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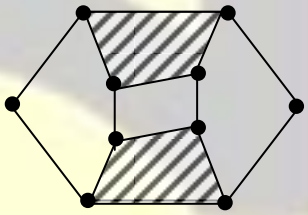
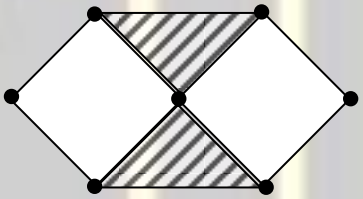
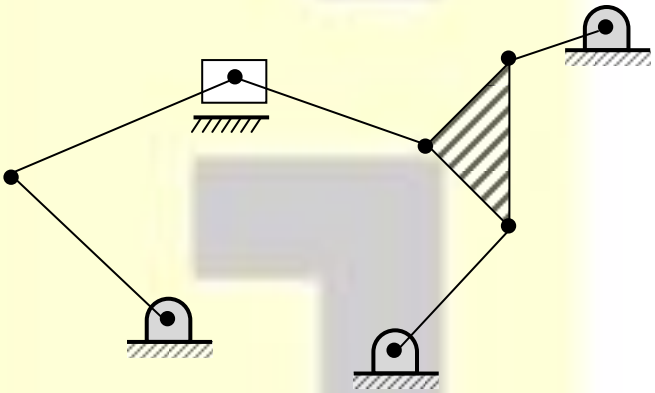


5.

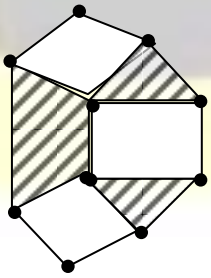


6.



[12 Marks]

(ii) Determine and show the structurally distinct (unique) inversions of the following 8-link kinematic chain:



[6 + 6 Marks]

(d) The turbine rotor of a ship has a mass of 2.5 tonnes and rotates at 1750 r.p.m. clockwise when viewed from the aft. The radius of gyration of the rotor is 320 mm. Determine the gyroscopic couple and its effect when (i) the ship turns right at a radius of 250m with a speed of 30km/hr, (ii) the ship pitches with the bow rising at an angular velocity of 0.7 rad/ s and (iii) the ship rolls at an angular velocity of 0.2 rad/ s.

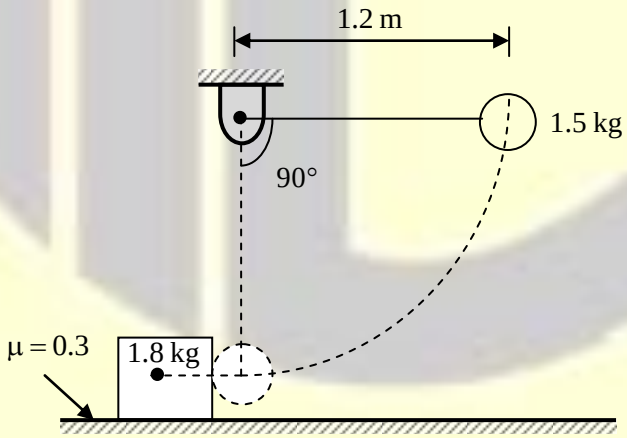
[12 Marks]

(e) What is the relationship between tensile and shear yield stresses as per (i) vonMises' criterion and (ii) Tresca's criterion?

The above relationships are to be derived by considering yielding under uniaxial tensile loading and under pure torsion.

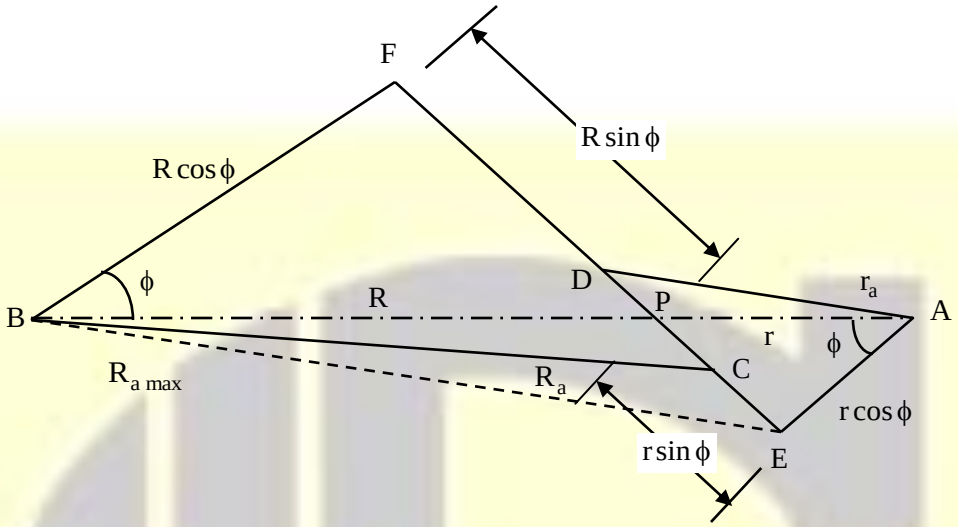
[12 Marks]

2. **(a)** A smooth sphere of mass 1 .5kg is released from rest in the position when the flexible string attached to it is horizontal. It hits centrally a stationary block of mass 1.8 kg kept on a surface, with the coefficient of friction between the block and the surface being 0.3. If the coefficient of restitution is 0.8, how far would the block move after impact?



[12 Marks]

(b) **(i)** Derive the formulation for path of contact of two gears A and B in contact as shown in the figure:



(ii) Each of two gears in a mesh has 48 teeth and a module of 8 mm. The teeth are of 20° in volute profile. The arc of contact is 2.25 times the circular pitch. Determine the addendum and contact ratio.

[10 + 10 Marks]

(c) A cam having a lift of 1.2 cm operates the suction valve of a four-stroke petrol engine. The least radius of the cam is 2 cm and nose radiusis0.3 cm. The crank angle of the engine when suction valve opens is 4° after t.d.c. and it is 50° after b.d.c. when the suction valve closes. The cam shaft has a speed of 960 r.p.m. The cam is of circular type with circular nose and flanks. It is integral with cam shaft and operates a flat-faced follower. Calculate (i) the maximum velocity of the valve, (ii) the maximum acceleration and retardation of the valve and (iii) the minimum force to be exerted by the spring to overcome inertia of the valve parts which weigh 250g.

[20 Marks]

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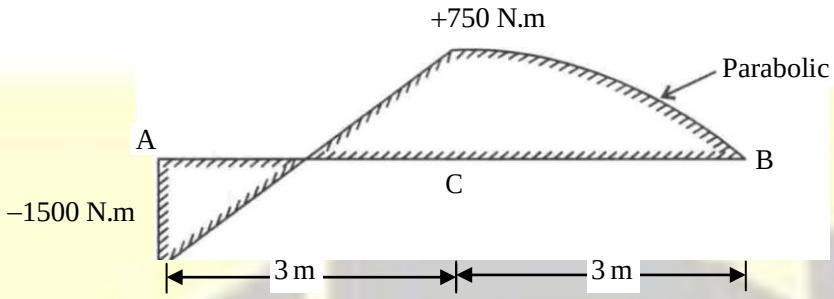
3. **(a)** Show the loading on the beam corresponding to the bending moment diagram shown in the figure. The beam is simply supported at A and B:



[20 Marks]

(b) A shaft1.7 cm diameter and 1:2 m long is held in long bearings. The weight of a disc at the centre of the shaft is 20kg. The eccentricity of the centre of gravity of the disc from centre of rotor is 0.03cm. The Young's modulus of material of the shaft is $2\times10^{6}\,\text{kg/cm}^2$. The permissible stress in the shaft material is $750\,\text{kg/cm}^2$. Calculate (i) the critical speed of the shaft and (ii) the range of speed over which it is un safe to run the shaft. Neglect weight of the shaft.

[20 Marks]

(c) **(i)** A bolted joint is used to connect two components. The combined stiffness of the two components is twice the stiffness of the bolt. The initial tightening of the nut results in a preload of 10 kN in the bolt. The external force of 7.5kN creates further tension in the bolt. The bolt is made of plain carbon steel 30C8, having tensile yield strength of $400\,\text{N/mm}^2$. There are coarse thread son the bolt. Calculate the tensile stress area of the bolt. The factor of safety specified is 3.

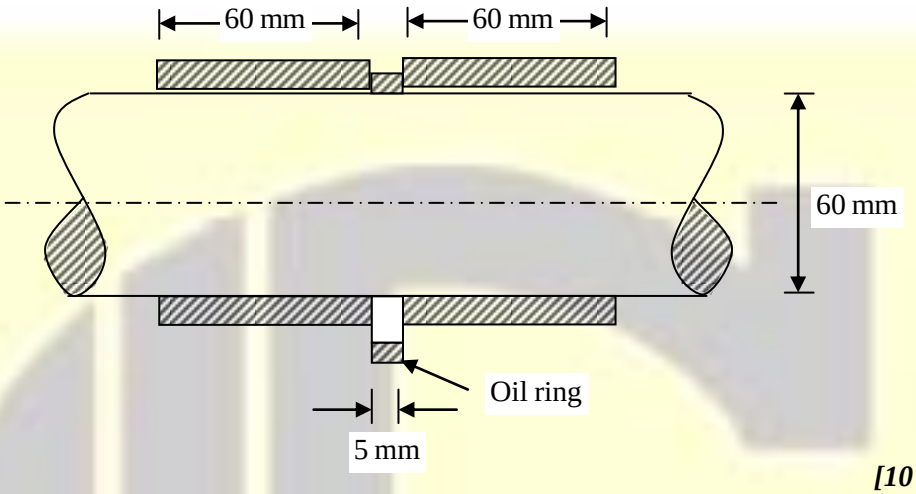
(ii) An oil ring of a shafttransmitting power is shown in the figure. Thereis no hydrodynamic action over 5 mm widthof the oil ring. The total radial load on the journal is 21 kN and the journal rotates at 1440 r.p.m.

$$\frac{c}{r}=0.8\times10^{-3};\ \frac{h_0}{c}=0.2$$

where c = radial clearance, r = radius and h_0 = minimum oil thickness

For the instant case, Sommerfeld number (S) = 0.0446

For this case, calculate the viscosity of lubricant:



[10 + 10 Marks]

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4. **(a)** A thick cylinder of 225 mm internal diameter has to be designed for a safe internal pressure of 50MPa.Calculate thethickness of the cylinder wall using maximum shear stress theory. The axial stress may be neglected in the calculation. The yield stress of the cylinder material is 260 MPa and the factor of safety is 2.

[20 Marks]

(b) A riveting machine isdriven bya motor of 4 kW. The actual time to complete one riveting operationis1.5 seconds and it absorbs 12 kN-m of energy. The moving parts including the flywheel are equivalent to 220 kg at 0.5 m radius. Determine the speed of the flywheel immediately after riveting, if it is 380 r.p.m. before riveting. Also determine the number of rivets closed per minute.

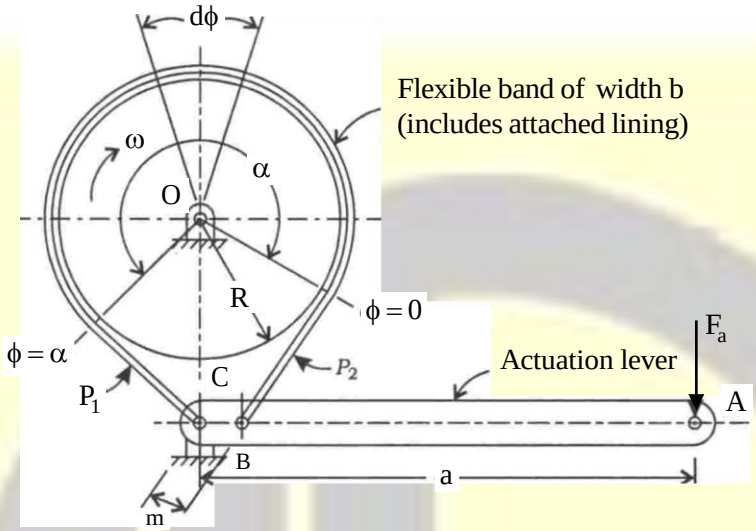
[20 Marks]

(c) Refer to the following figure of the drum brake.

Prove that the braking torque (T_f) can be expressed as

$$T_f = P_2 R\left(e^{\mu\alpha} - 1\right) \text{ and } T_f = bR^2 p_{max}\left(1 - e^{-\mu\alpha}\right)$$

where R = drum radius, b = width, p = pressure at any point in the arc of contact and P = tensile force in the band at the same point:



Overall layout

[20 Marks]

SECTION-B

5. **(a)** Zirconium has an HCPcrystal structureand a density of6.51g/cm^3.Theatomic weight of zirconium is 91.22 g/mol. Answer thefollowing:

(i) What isthe volume ofitsunit cellincubic metres?

(ii) If the c / a ratio is1 .593, compute the values of c and a.

[12 Marks]

(b) Giveat least four comparisons between honing and lapping. Alsolistatleast three functions performed byelectrolyte inelectrochemicalmachining (ECM) process.

[12 Marks]

(c) List five causes of service failure giving example of at least one mechanical component in which it occurs. Also list at least five causes of vibration in mechanical system.

An automobile has four tyres. The constant failure rates of tyres 1, 2, 3 and 4 are 0.00001 failure/hour, 0.00002 failure/hour, 0.00003 failure/hour and 0.00003 failure/hour respectively. The automobile cannot be driven when anyone of the tyres punctures. Find the mean time tofailure oftheautomobile with respect totyres and reliability foroperating the automobilefor500hours without failure oftyres.

[12 Marks]

(d) Youare a consultant foroperations of a firmthat deals with just oneitem that costs ₹ 45.The firmbuys the item wholesale from a supplier andsellsretail.Youhavecompiled the following details forthe item

Parameters	Values
Annual demand	4380
Workdays/year	365
Opportunity cost of investment in inventory	12.5%
Fixed cost of order generation per order	₹22
Cost of inspecting items received	₹ 3
Cost due to breakage or spoilage	9.5%
Warehouse rental	6.5%
Insurance costs	1.5%

The following twooptions are available toyou

Option1:The supplier can supply allitems at once

Option 2:The supplier can supply 15 items perday

Which oftheoptions would you recommend to the firm and why?

[12 Marks]

(e) Compare between hydraulicandelectrical actuators'characteristicsinthe following pointsinbrief:

(i) Stiffness of the actuators

(ii) Need of reduction gear

(iii) Need of braking device

(iv) Working in low and high temperature

(v) Working of the actuators

(vi) Maintenance need of the actuators

[12 Marks]

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6. **(a)** **(i)** Three jobsareto be processed in a jobshop consisting of three machines.Each job requires three operations and they are to be carried out in $1 \rightarrow 2 \rightarrow 3$ order. The following table indicates the machines required as well as processing time (in hours) required foreach operation.Initially, all jobs and machines are available. Compute the makes pan by drawing Gantt chart indicating every operation of each job using shortest processing time dispatching rule and break ties with least work remaining rule:

	Machine required for operation			**Processing time of operation**		
	1	2	3	1	2	3
Job 1	M1	M2	M3	4	2	3
Job 2	M1	M3	M2	2	4	4
Job 3	M3	M2	M1	3	5	3

(ii) Explain thephysics of arcinitiation inarcwelding. Why is arc initiation difficult in plasma arc welding? Why is plasma arc welding called as plasma arc welding despite the fact that plasma is present in allother arc welding processes?

[10 + 10 Marks]

(b) (i) Brieflydescribe thetechniques that may beused forgalvanic protection. Alsoexplain whycold-worked metalsaremoresusceptible tocorrosion thannon-cold-worked metals.

(ii) Writethepossible oxidation andreduction half-reactions that occur when magnesium is immersed in each of the following solutions:

(1) HCl

(2) HCl solution containing dissolved oxygen

(3) HCl solution containing dissolved oxygen and in addition Fe^{2+}ions

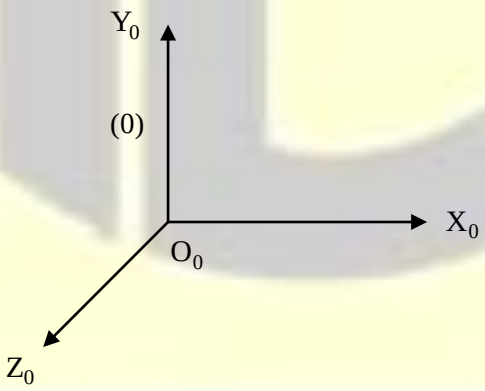
In which of the above solutions would you expect the magnesium to oxidize rapidly and why?

[10 + 10 Marks]

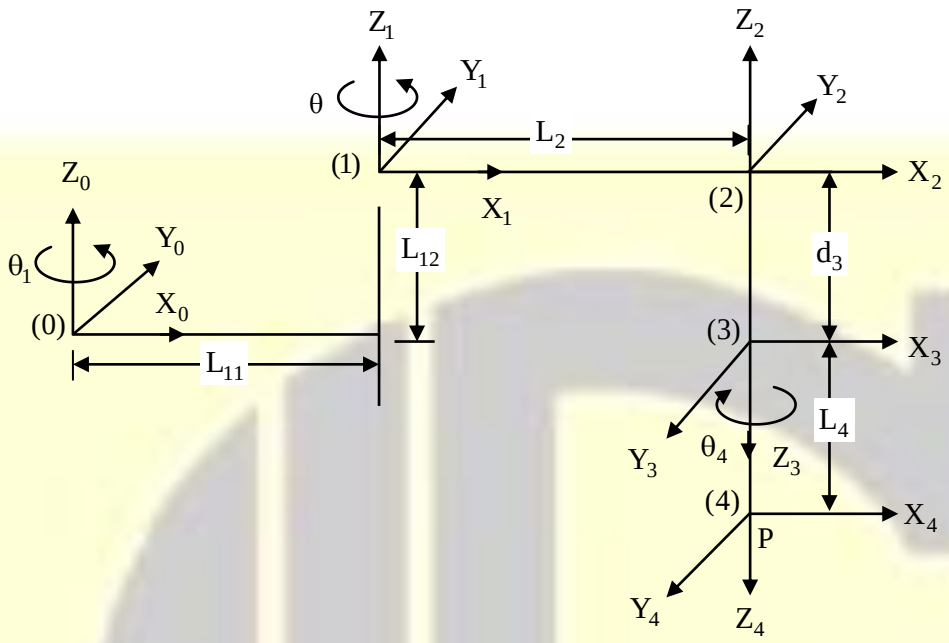
(c) (i) Theforward kinematic model of a planar 2 DOF (RR) manipulator with link lengths $a_1 = a_2 = 10$ units, is given by the matrix

$$o_{T_2} = \begin{bmatrix} 0 & -1 & 0 & 10/\sqrt{2} \\ 1 & 0 & 0 & 10+10/\sqrt{2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Draw the last frame {2}, with respect to{O} frame, by locating its position and its orientation. The initial frame, frame {O}is givenas



(ii) For the given frames of SCARA manipulator, generate the DH parameters table:



[10 + 10 Marks]

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7. **(a)** **(i)** How does permeability of molding sand vary with the moisture content?

Explain with the help of neat sketches. Also explain the role of adding organic additives in the molding sand.

(ii) A dimension 57.975 mm is required to be set with the help of slip gauge blocks as accurate as possible. Two slip gauge block sets M45 (Grade O) and M112 (GradeII) are available. Therangeand number of pieces in each setaregivenbelow:

Set M45 (Grade 0)			**Set M112 (Grade II)**		
Range (mm)	**Steps (mm)**	**Number of blocks**	**Range (mm)**	**Steps (mm)**	**Number of blocks**
1.001 to 1.009	0.001	9	1.0005	–	1
1.01 to 1.09	0.01	9	1.001 to 1.009	0.001	9
1.1 to 1.9	0.1	9	1.01 to 1.49	0.01	49
1.0 to 9.0	1.0	9	0.5 to 24.5	0.5	49
10.0 to 90.0	10.0	9	25.0 to 100.0	25.0	4

The permissible errors in 1/100000 mm units in the mean length of Grade O and Grade II are given below:

Length (mm)	0 to 20	20 to 60
Grade II	+50 –20	+80 –50
Grade 0	±10	±15

Find the slip gauge that you will prefer, with reasons.

[10 + 10 Marks]

(b) (i) It is possible to drill a 25 mm nominal hole to an accuracy of $25^{+0.02}_{-0.02}$ mm using standard drill and drilling machine available. A shaft is to be machined to obtain a clearance fit in the above hole such that minimum allowance should be 0.01 mm and maximum clearance should not be more than 0.07 mm. Find the tolerance on the shaft. Also state why hole basis system of fits is generally preferred over shaft basis system of fits.

(ii) List the manufacturing situations where FMS technology can be successfully employed. Also give at least four differences between dedicated and random-order FMS.

[10 + 10 Marks]

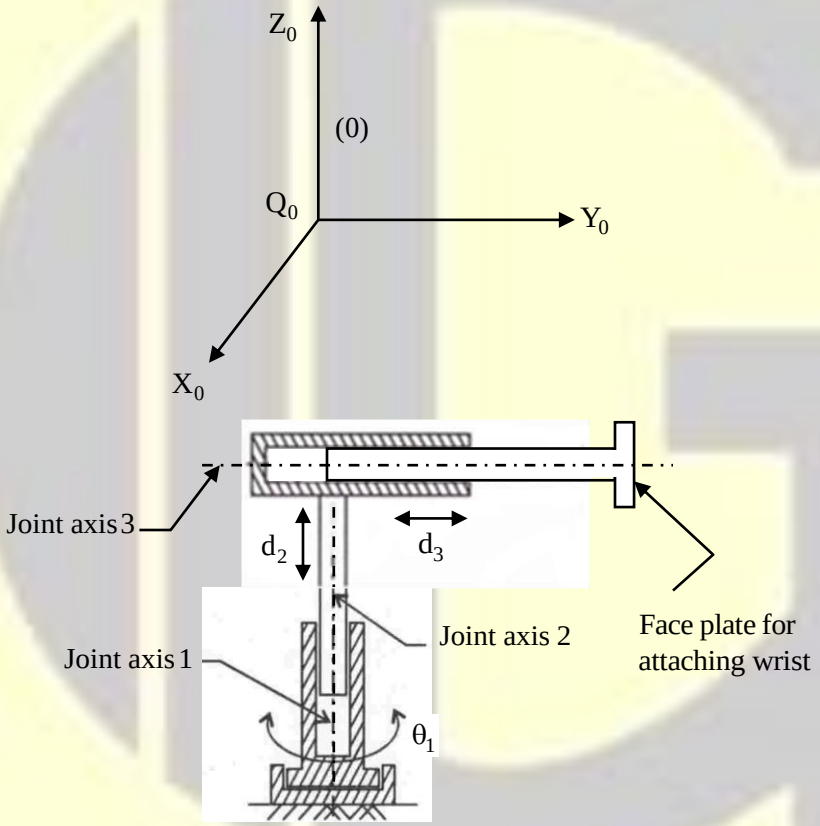
(c) Formulate the forward kinematic model of the 3 DOF (RPP) manipulator arm, shown in the figure, by-

(i) generating and drawing the frames using DH rules;

(ii) generating theDHparameters tablefromtheassignedframes;

(iii) generating the individual transformation matrices ${}^{0}T_1, {}^{1}T_2, {}^{2}T_3$ and the overall transformation matrix ${}^{0}T_3$..

Also draw the last frame {3}, if θ_1, d_2 and d_3 are given respectively as 0°, 10 units and 10 units, with reference to the given initial frame:



The homogeneous transformation matrix ${}^{i-1}T_i$ is given as

$$ {}^{i-1}T_i = \begin{bmatrix} c\theta_i & -s\theta_i c\alpha_i & s\theta_i s\alpha_i & a_i c\theta_i \\ s\theta_i & c\theta_i c\alpha_i & -c\theta_i s\alpha_i & a_i s\theta_i \\ 0 & s\alpha_i & c\alpha_i & d_i 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

[20 Marks]

8. **(a)** A 12.7 mm diametersteel wire is drawnto obtain 35.5% reductioninareaby drawingthrougha conicaldie of 6° semi-cone angle.Thecoefficientof frictionbetween the wire material and die materialat conicalportion of die is 0.1andthereisno backpull.Thetensileyieldstrengthof theoriginalspecimenis207 MPa and is 414 MPa at a strainof 0.5. Assuminglinearstressrelationship for the wire material and efficiency of electrical motor as 98%, find the drawing power and maximum possible reduction.

[20 Marks]

(b) **(i)** Thetransformationofframe{i-1}toframe{i}consistsoffourbasic transformations asfollowing:

(1) A rotation about Z_{i-1} axis by an angle θ_i

(2) A translation along Z_{i-1} axis by distance d_i

(3) A translation along X_i axis by distance a_i

(4) A rotation about X_i axis by an angle α_i

Generate the individual transformation matrices and also the composite transformation matrix ${}^{i-1}T_i$, due to the above successive transformations. If all the above parameters (DH) are zero, what will be the composite transformation matrix?

(ii) Explain thefollowingsensorcharacteristics inbrief:

(1) Range

(2) Resolution

(3) Reliability

(4) Repeatability

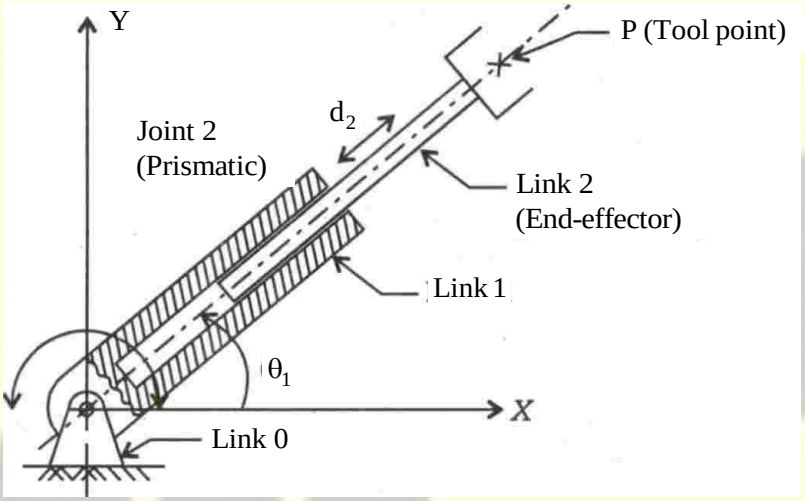
(5) Sensitivity

[10 + 10 Marks]

(c) **(i)** Generate a forward kinematic model of the given two degrees of freedom (RP) planar manipulator.

(ii) Determine the joint variables (θ_1, d_2) for the above manipulator using inverse kinematic model, if the position and orientation of the end-effector aregivenbythefollowingmatrix:

$$T_B = \begin{bmatrix} 0.707 & 0 & 0.707 & 70.71 \\ 0.707 & 0 & -0.707 & -70.71 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



Given that

$$^{i-1}T_i = \begin{bmatrix} c\theta_i & -s\theta_i c\alpha_i & s\theta_i s\alpha_i & a_i c\theta_i \\ s\theta_i & c\theta_i c\alpha_i & -c\theta_i s\alpha_i & a_i s\theta_i \\ 0 & s\alpha_i & c\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

[20 Marks]